Working Control Device

BACKGROUND OF THE INVENTION

The invention relates to a technology of
obtaining an object workpiece by working a work
material in a way that controls a cutting machine on
the basis of design information defined on a computer.

There has hitherto been known a device
contrived to automatically perform working by
controlling a working machine on the basis of CAD
data, etc.. For instance, there is proposed a
control device for a machine tool that includes tool
route determining means for: inputting workpiece data
about workpiece configuration data concerning a final
workpiece configuration and workpiece data about a
material and a configuration of the workpiece;
generating a workpiece working tool route on the
basis of data stored with machine s data containing
characteristics of a machine body such as a column, a
bed, etc. of the machine tool, and tool s data about
a working tool which contain a deformation, etc. at a
working time when this tool is attached to a holder;
and determining working conditions such as a rotating
speed of a main shaft, a feeding speed, etc. of the
machine tool.

In the conventional device, a working process
is determined by a predetermined algorithm which

involves using generally three-dimensional CAD data and databases, thereby actualizing automation and standardization. In this case, contents of the database are not automatically updated unless a man changes them, and a result of working is not reflected in the contents of the database. Further, for adjusting the working process outputted from a system, it was required that a man having special knowledge adjusts the database.

Therefore, a so-called condition library is main as the database, and there was no system having, as intra-system function, a role performed by an operator such as optimizing the conditions and storing working phenomena, and automatically generating NC data by optimally combining these pieces of information.

Further, as to a so-called feedback system, there exists a working condition correcting device for measuring dimensions of a plurality of workpieces, obtaining an error between a value of this time and a value of the last time of a specified value thereof, and correcting it, however, there exists none of devices used for correcting a feed and the number of revolutions of a working machine in real time while monitoring a main shaft load and working phenomena such as a chatter, etc. during cutting of one workpiece or for correcting the cutting conditions

when working next time.

Moreover, in a conventional working control device, a feedback of the result of working to the database is intended for what can be expressed as a measured numerical value such as the number of revolutions, a feed speed, a working time, a dimensional accuracy, etc., wherein an intention and a judgment of the operator is not reflected therein as in a case where if preferable of fitting to other parts, an acceptance is gained even when, for instance, the measured value deviates from a dimensional tolerance, and a case where it is sufficient if a molding product is separable from a die even when the surface roughness of an insert part of a molding portion is rougher than a designated value in a resin molding product die assembly.

Moreover, the tool and the process have hitherto been determined from an experience of the operator. In a three-dimensional CAM that is widely utilized at the present, it is not yet automated as to which tool is used and which process this tool is used.

Note that there was proposed a system having a function of designing the working process based on the database stored with a type of a product to be worked, a tool and a process in a way that makes them mapping to each other, however, there is not any

system for designing the working process from a tool
library retaining a given 3D configuration without
having such a type of database.

Further, a system exists, wherein a small tool
is determined by calculating a cutting quantity and a
cutting residual in sequence from the largest
diameter, however, there is no system for calculating
a maximum tool diameter that should be used, from a
minimum tool diameter that is to be used by the
operator for finishing, and a great deal of
experiences of the operator were needed.

SUMMARY OF THE INVENTION

In the devices described above, the following
problems are pointed out.

(a) Know-how of the well-experienced operator
who creates the NC data can not be reflected in
cutting conditions by other operators, and therefore
the same failure is to be repeated between different
operators.

(b) Education and training of the operator who
creates the NC data is time-consuming.

(C) A result of creating the NC data differs
depending on the know-how of the operator, and there
occurs a difference in working state.

(d) Generally, cutting working conditions are
written on the paper or left as a memory of the well-

experienced operator, and are difficult to be accurately stored and utilized by others.

(e) As the working machine is changed, new working know-how needs accumulating.

5   (f) A working system for analyzing for drawing optimal working conditions takes too much time and is unsuited to a working spot in which the time is an important factor for decreasing the costs down and for management the processes.

10   (g) Whether the tool and the process can be adequately determined or not, depends on the experience of the operator, and hence there arise problems such as a scatter in working quality, non-efficient cutting and a use of improper tool.

15 Moreover, in the case of the system including the database stored with a classification of a product to be worked in a way that make them mapping to a tool and a process, even an less-experienced operator is able to handle it to some extent but is unable to

20 determine a proper tool and process with respect to configurations that the database does not retain. Accordingly, in a case where a man determines the tool, to start with, a tool having a diameter suited to rough working is determined based on the

25 experience, and subsequently, the tools are determined in sequence from the largest diameter such as a tool for intermediate finishing and a tool for

final finishing. To replace this with the system, in
the case of determining the tools in sequence from
the largest diameter, the calculations are performed
in sequence from the tool having the largest diameter
5   so far as they are usable, and therefore this is non-
efficient.

The invention was made to solve the problems
given above. Namely, the invention aims at providing
a technology enabling the working under proper
10   working conditions by searching for a working case
corresponding to characteristics of a configuration
to be worked and setting the working conditions based
on this working case.

The invention adopted the following means in
15   order to accomplish the object.

In a working control device, a working control
program and a working control system of the invention,
configuration information about characteristics of a
three-dimensional configuration is obtained from
20   design data of an object workpiece, a working case is
searched out based on the configuration information
from a working case storage unit for storing working
conditions, as a working case, of the working
conducted in the past, working conditions are
25   determined based on the working case searched out by
the case searching unit, and a working machine is
controlled based on the working conditions.

A contrivance of the invention is, putting an emphasis on similarities of a working tool, a working process, further, a behavior of a cutting tool during the working and a result of the working if there are

5   similarities in configuration between design data of the object workpiece that should be worked and the working cases conducted in the past, that the working case is accumulated and searched out based on characteristics of the configuration, and the working

10 conditions are determined based on this working case, whereby a result of the working in the past can be utilized. Namely, even a less-experienced operator can perform the working based on the past examples accumulated on a database. Moreover, failure cases

15 can be accumulated together with successful cases after the cutting/working, and it is therefore possible to prevent similar failures from being repeated.

      <<Readable-by-Computer Recording Medium>>

20   The invention may also be a recording medium in such a form that the program is recorded on a readable-by-computer recording medium. Then, the computer reads and executes the program on this recording medium, whereby the functions thereof can

25 be provided.

      Herein, the readable-by-computer recording medium connotes a recording medium capable of

accumulating information such as data, programs, etc. electrically, magnetically, optically and mechanically or by chemical action, which can be read from the computer. What is demountable out of the

5 computer among those recording mediums are, e.g., a flexible disk, a magneto-optic disk, a CD-ROM, a CD-R/W, a DVD, a DAT, an 8mm tape, a memory card, etc..

Further, a hard disk, a ROM (Read Only Memory) and so on are given as recording mediums fixed to the

10 computer.

As explained above, the invention enables the working under the proper working conditions by searching for the working case in accordance with the characteristics of the configuration to be worked and

15 setting the working conditions based on this working case.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a working

20 control system according to the invention.

FIG. 2 is a schematic architecture diagram of a working control device.

FIG. 3 is an explanatory chart of a working control procedure.

25 FIG. 4 is a flowchart of calculating maximum external configuration dimensions.

FIG. 5A-5B are an explanatory view of

calculating the maximum external configuration dimensions.

FIG. 6 is an explanatory view of calculating the maximum external configuration dimensions.

5   FIG. 7 is a flowchart of calculating a removal volume.

FIG. 8A-8D are an explanatory view of calculating the removal volume.

FIGS are a view of calculating the removal volume.

10   FIG. 9A-9B are an explanatory view of calculating the removal volume.

FIG. 10 is a flowchart of obtaining surface information.

FIG. 11 is an explanatory view of obtaining the surface information.

15   surface information.

FIG. 12 is a flowchart of obtaining a minimum concave shape radius.

FIG. 13A-13B are an explanatory view of obtaining the minimum concave shape radius.

20   FIG. 14 is a flowchart of obtaining a largest concave shape radius.

FIG. 15A-15D are an explanatory view of obtaining the largest concave shape radius.

FIG. 16 is an explanatory view of calculating a

25   maximum depth.

FIG. 17A-17B are an explanatory view of obtaining a working boundary.

FIG. 18 is a flowchart of calculating blank dimensions.

FIG. 19 is an explanatory view of calculating the blank dimensions.

5   FIG. 20 is an explanatory diagram of a cutting working case database.

FIG. 21 is an explanatory diagram of determining working conditions.

FIG. 22 is an explanatory diagram of work

10   control based on working surface roughness.

FIG. 23 is an explanatory diagram of the work control based on the working surface roughness.

FIG. 24 is a flowchart of the work control based on a main shaft load.

15   FIG. 25A-25B are an explanatory diagram in the case of obtaining a tool diameter based on a cutting range boundary line.

FIG. 26 is a flowchart of obtaining the tool diameter based on the cutting range boundary line.

20   FIG. 27 is a flowchart of obtaining the tool diameter based on the cutting range boundary line.

FIG. 28 is a flowchart of obtaining a tool protrusion quantity based on a cutting depth.

FIG. 29 is an explanatory diagram in the case

25   of obtaining a tool protrusion quantity based on a cutting depth.

FIG. 30 is an explanatory diagram in the case

of obtaining a type of a working tool based on the surface information.

FIG. 31 is a flowchart of control of detecting a tool line-time or breakage.

FIG. 32 is a flowchart of the control of detecting the tool line-time or breakage.

FIG. 33A-33C are an explanatory diagram in the case of selecting a plurality of tools as a set.

FIG. 34 is a flowchart of control of selecting the plurality of tools as a set.

FIG. 35 is a flowchart of the control of selecting the plurality of tools as a set.

FIG. 36A-36D are an explanatory diagram of control of determining a tool and a working process.

FIG. 37 is a flowchart of control of determining the tool and the process from a target time .

FIG. 38A-38B are an explanatory diagram of the control of determining the tool and the working process.

FIG. 39 is a flowchart of the control of determining the tool and the process from a reduction time.

DETAILED DESCRIPTION OF THE INVENTION

A working system will be explained based on drawings in FIGS. 1 through 35 by way of embodiments

of the invention.

<System Architecture>

FIG. 1 is a block diagram showing an architecture of the working system in an embodiment.

The working system in the embodiment is constructed of a working control device 1 and a working machine 2 controlled by this working control device 1.

§1. Working Control Device

The working control device 1 includes a pre-working input unit 11, a three-dimensional configuration characteristic extraction unit (corresponding to a configuration characteristic extraction unit) 12, a case searching unit 13, a cutting working condition auto setting unit (corresponding to a working condition setting unit) 14, a cutting working case database (corresponding to a working case storage unit) 15, a judgment criterion database (corresponding to a judgment criterion storage unit) 16, a working case registration unit 17, a post-working input unit 18, an auto NC data creating unit (control unit) 19, and a monitoring unit 10.

This pre-working input unit 11, which is an operation unit such as a keyboard, a touch panel, etc. and is operated by an operator, accepts an input of information(object workpiece information) about an

object workpiece. The information about the object workpiece is information that is not contained in design data among pieces of data necessary for working, such as a classification, rigidity, etc. of

5   a work material.

The three-dimensional configuration characteristic extraction unit 12, as will be described later on, obtains configuration information on characteristics of a three-dimensional

10   configuration from three-dimensional CAD data (corresponding to design data) of the object workpiece).

The case searching unit 13 searches out a working case from the cutting working case database

15   15 on the basis of the configuration information obtained by the three-dimensional characteristic extraction unit 12.

The cutting working condition auto setting unit 14 determines working conditions based on the working

20   case searched out by the case searching unit 13.

The cutting working case database 15 is stored with working conditions, as working cases, of the workings conducted in the past.

The judgment criterion database 16 is stored,

25   as information serving as judgment criteria for the working conditions, with a working condition threshold value database 16a, a tool library 16b, a

cutting condition database 16c, etc..

The working case registration unit 17 stores the working case storage unit with information of the working machine 2 that has been acquired by the monitoring unit 10 in a way that makes it as a working case mapping to the configuration information.

The post-working input unit 18, which is an operation unit such as a keyboard, a touch panel, etc. and is operated by the operator, accepts an input of information about whether the working is preferable or not. Note that one single keyboard serves as both of the pre-working input unit 11 and the post-working input unit 18 in the embodiment.

The auto NC data creating unit 19 controls the working machine 2 on the basis of the working conditions set by the cutting working condition auto setting unit 14.

The monitoring unit 10 acquires the information of the working machine 2 when the auto NC data creating unit 19 performs controlling based on the working conditions.

The working control device 1 may be a dedicated electronic device constructed of electronic circuits (hardware) designed exclusively as the respective units 10 ~ 19, and may also be a device in which the functions of the respective units 10 ~ 19 are actualized softwarewise on a general-purpose computer.

Note that the working control device 1 in the embodiment is, as shown in FIG. 2, a general type of computer.

As illustrated in the same Figure, the working
5   control device 1 includes, within a main body 31, an arithmetic processing unit 32 constructed of a CPU (central processing unit), a main memory, etc., a storage device (hard disk) 33 stored with data and software for the arithmetic processes, an
10   input/output unit (I/O) 34 and so on.

Connected properly to the input/output unit 34 are an input device such as a keyboard (the pre-working input unit 11, the post-working input unit 18), the mouse, etc, an output device such as a
15   display device, a printer, etc., and an interface for transmitting and receiving the information to and from other devices.

An operating system (OS) and application software (a working control program) are installed
20   into the storage device 33. Further, the cutting working case database 15 and the judgment criterion database 16 are built up in the storage device 33.

The arithmetic processing unit 32 executes the arithmetic processes according to the working control
25   program, thereby functioning as the three-dimensional configuration characteristic extraction unit (corresponding to the configuration characteristic

extraction unit) 12, the case searching unit 13, the cutting working condition auto setting unit 14, the working case registration unit 17, the auto NC data creating unit 19 and the monitoring unit 10.

5 §2. Working Machine

The working machine 2 in the embodiment includes a cutting working unit 21, a working machine control unit 22 and a magazine 23.

This cutting working unit 21 is constructed of

10 an installation base for attaching a work material, a cutting tool, a main shaft for fitting this tool, a rotation driving unit for the main shaft, a feed driving unit for feeding in X-axis, Y-axis and Z-axis directions, etc., and performs cutting/working of the

15 work material.

The working machine control unit 22 controls the cutting working unit 21 on the basis of NC data. This working machine control unit 22 includes a sensor unit 22A for detecting a working state of the

20 working machine 2, a cutting control unit 22B for controlling the cutting working unit 21 in accordance with the working state detected by the sensor unit 22a and the NC data, a magazine management unit 22c for giving an instruction of acquiring information of

25 the tool housed in the magazine and an instruction of replacing the tool, and so on.

The magazine 23 houses the tool used in the

cutting working unit 21. Further, the magazine 23
has a function (ATC) of replacing the tool used in
the cutting working unit 21 in accordance with the NC
data.

5   <Working Procedures>

Next, working control procedures in the system
will be described by use of FIGS. 3 ~ 35.

§1. Basic Procedure

In the working control device 1, upon an input

10   of three-dimensional CAD data 100 of an object
workpiece, as shown in FIG. 3, the three-dimensional
configuration characteristic extraction unit 12
obtains configuration information about
characteristics of a three-dimensional configuration

15   from the three-dimensional CAD data 100 in step S1.

Further, the operator inputs pieces of object
workpiece information such as a classification, a
rigidity of the work material by operating the pre-
working input unit 11 in step S2, the pre-working

20   input unit 11 accepts this input and inputs it to the
case searching unit 13.

In next step S3, the case searching unit 13
searches out a working case from the cutting working
case database 15 with the configuration information

25   being as a search key.

In next step S4, the cutting working condition
auto setting unit 14 judges whether or not the

working case was obtained in step S3, moves to step

S5 if obtained, and determines working conditions

based on this working case and the information in the

judgment criterion database 16. Moreover, if the

5   working case was not obtained in step S3, moving to

step S6, wherein the cutting working condition auto

setting unit 14 determines the cutting working

conditions on the basis of the configuration

information obtained by the thee-dimensional

10   configuration characteristic extraction unit 12, the

information accepted by the pre-working input unit 11

and the information in the judgment criterion

database 16. Herein, the cutting condition database

16c of the judgment criterion database 16 is

15   previously stored with maker recommendation values

and default values of the working conditions in

accordance with the three-dimensional configuration

and the classification of the work material. The

cutting working condition auto setting unit 14, if

20   unable to obtain the working case, determines the

working conditions by referring to the maker

recommendation values and the default values in

accordance with the configuration information, etc..

In next step S7, the auto NC data creating unit

25   19 creates NC data based on the working conditions

determined by the cutting working condition auto

setting unit 14, and transmits the NC data to the

working machine 2 via the interface of the I/O 34.
On the other hand, the working machine 2 effects,
based on the NC data, the cutting/working.

In next step S8, the monitoring unit 10
receives the information detected by the sensor unit
22a and monitors the working state in the working
machine 2.

The auto NC data creating unit 19, in step S9,
judges whether the working control is finished or not,
repeats steps 7 and 8 if not finished, and moves to
step S10 if finished.

In step S10, the working case registration unit
17 registers, in the cutting working case database 15,
the information (working conditions) as a working
case that has been detected by the monitoring unit 10
in a way that makes it mapping to the configuration
information inputted to the cutting working condition
auto setting unit 14 on the occasion of performing
this working and to the information inputted from the
pre-working input unit 11.

Thus, the working control device 1 in the
embodiment determines the working conditions based on
the working case and is therefore contrived so that
even a less-experienced operator can do the same
working as a well-experienced person does. Further,
the working control device 1 registers the result of
working in the cutting working case database 15, and

hence the result of working can be shared with other persons.

§2. Details of Working Procedures

Next, details of the working procedures will be explained. All of these procedures must not necessarily be executed and may be executed by arbitrarily combining the required procedures on the occasion of working in the working system.

2-1. [Extraction of Dimensions of Maximum External Configuration]

FIG. 4 is an explanatory chart of a procedure in which the three-dimensional configuration characteristic extraction unit 12 extracts dimensions of a maximum external configuration as configuration information from the three-dimensional CAD data 100 in step S1.

The three-dimensional configuration characteristic extraction unit 12 divides, based on the three-dimensional CAD data 100, surfaces of a three-dimensional model (an object workpiece) into, as shown in FIG. 5A, minute polygonal shapes (triangles in this example, which will hereinafter be called facets) (step S11, which will hereinafter be abbreviated such as S11), thereafter, as shown in FIG. 5B, obtains X-coordinates, Y-coordinates and Z-coordinates (F_n (X_n, Y_n, Z_n), F_{n+1} (X_{n+1}, Y_{n+1}, Z_{n+1}), F_{n+2} (X_{n+2}, Y_{n+2}, Z_{n+2})…) of three vertexes of the

facet, and repeatedly performs the same calculation with respect to all the facets (S12 ~ 14). The three-dimensional configuration characteristic extraction unit 12 obtains the X-coordinates, Y-coordinates and Z-coordinates of the vertexes of all the faces and acquires the minimum X-coordinates, Y-coordinates and Z-coordinates and the maximum X-coordinates, Y-coordinates and Z-coordinates by making comparisons between the coordinates of the vertexes of all the facets (S15, S16).

The three-dimensional configuration characteristic extraction unit 12 subtracts the minimum X-value from the maximum X-value obtained as above, and similarly makes the calculations with respect to the Y-coordinates and the Z-coordinates (S17), thereby obtaining, as shown in FIG. 6, a maximum X-directional length, a maximum Y-directional length and a maximum Z-directional length of the three-dimensional model and setting them as maximum external configuration dimensions (configuration information) (S18).

2-2. [Calculation of Removal Volume]

FIG. 7 is an explanatory chart of a procedure in which the three-dimensional configuration characteristic extraction unit 12 acquires a removal volume as configuration information from the three-dimensional data 100 in step S1.

The three-dimensional configuration
characteristic extraction unit 12 divides the
surfaces of the three-dimensional model (FIG. 8A)
represented in the three-dimensional CAD data 100

5   into facets as shown in FIG. 8B (S21), thereafter
creates triangles by projecting, as illustrated in
FIG. 8C, the respective facets on an X-Y plane, i.e.,
a fitting surface to the working machine (S22),
connects the facets to corresponding vertexes of the

10   triangles formed by projecting the facets onto the X-
Y plane (S23), obtains a volume of a triangle pole
(FIG. 8D) configured by three sides of the facet,
three sides of the triangle formed by projecting the
facet onto the X-Y plane, and three line segments

15   that connect the facet to corresponding vertexes of
the triangle formed by projecting the facet onto the
X-Y plane (FIG. 8D)(S24), obtains volumes with
respect to all the facets by repeating this (S25),
and thus calculates a total sum of the volumes, i.e.,

20   a value of the three-dimensional model (S26).

Thus, after calculating the volume of a three-
dimensional model 91 in FIG. 9A, as described above,
a maximum X-directional length, a maximum Y-
directional length and a maximum Z-directional length

25   are obtained with respect to the 3-cutting working
unit 21, a maximum model external configuration
volume is obtained by multiplying the maximum X-

directional length, the maximum Y-directional length
and the maximum Z-directional length (S27), and a
volume of the 3-cutting working unit 21 is subtracted
from this maximum external configuration volume,

5   thereby acquiring a volume removed by the
cutting/working as shown in FIG. 9B (S28).

2-3. [Calculation of Surface Information]

FIG. 10 is an explanatory chart of a procedure
in which the three-dimensional configuration

10   characteristic extraction unit 12 acquires surface
information as configuration information from the
three-dimensional data 100 in step S1.

The three-dimensional configuration
characteristic extraction unit 12 divides, based on

15   the three-dimensional CAD data 100, surfaces of a
three-dimensional working configuration into facets
(S31, and thereafter, as shown in FIG. 11, obtains
normal line vectors of all the facets (S32). The
three-dimensional configuration characteristic

20   extraction unit 12 judges whether or not the normal
line vectors (directions) of these facets are
parallel with the Z-axis, i.e., a working axis (S33),
obtains areal sizes of the facets and Z-values about
only the facets showing the parallelism (S34, S35),

25   sorts out the areal sizes per Z-value (S36), and
acquires the surface information, according to the Z-
values, of the flat surfaces parallel with the X-Y

plane (S37). Note that the facets of which the
normal line vectors are judged not to be parallel
with the working axis in step S33 are excluded from
the information (S38).

5   As for a surface, perpendicular to the working
axis, in the three-dimensional model, viz., the
surface that can be machined by a flat end mill, an
areal size per position in the Z-axis direction, i.e.,
the areal size presumed so that it can be machined at
10   one time, is thereby acquired; and the cutting
working condition auto setting unit 14, on the
occasion of determining the working conditions, based
on this piece of surface information, selects a tool
having a large diameter if the areal size is large
15   and a tool having a small diameter if the areal size
is small.

2-4. [Calculation of Minimum Concave Shape
Radius dimension]

FIG. 12 is an explanatory chart of a procedure
20   in which the three-dimensional configuration
characteristic extraction unit 12 acquires a minimum
concave shape radius dimension as configuration
information from the three-dimensional data 100 in
step S1.

25   The three-dimensional configuration
characteristic extraction unit 12 classifies, based
on the three-dimensional CAD data 100, the surfaces

of the three-dimensional model into flat surfaces and surfaces other than those, i.e., curved surfaces (S41), extracts surfaces of the curved surfaces (S42), and excludes the surfaces other than those from the

5   information (S48).

Then, the three-dimensional configuration characteristic extraction unit 12, as shown in FIG. 13A, divides the curved surface respectively in U- and V-directions at an error allowable value interval

10   when creating the three-dimensional model (S43), acquires a radius from three intersections between dividing lines adjacent to each other in the U- and V-directions (S44), as shown in FIG. 13B, obtains a direction of the Z-component of the normal line

15   vector acting outwards from a center of the acquired radius (S45), seeks out whether this direction of the Z-component is coincident with a (-) Z-direction (S46), judges, if not coincident, that it is a convex shape radius and excludes it from the information

20   (S49), then judges, if coincident, that it is a concave shape radius (S46), and acquires a minimum concave shape radius among these radiuses (S47).

With this, the cutting working condition auto setting unit 14, on the occasion of determining the

25   working conditions, obtains a diameter of the tool used for finishing on the basis of this minimum concave shape radius dimension.

2-5. [Calculation of Largest Concave Shape
Radius Dimension]

FIG. 14 is an explanatory chart of a procedure
in which the three-dimensional configuration
5   characteristic extraction unit 12 acquires a largest
concave shape radius dimension as configuration
information from the three-dimensional data 100 in
step S1.

The three-dimensional configuration
10   characteristic extraction unit 12 acquires, in the
same way as the above-mentioned, the surfaces (FIG.
15A) having the concave shapes (S41 ~ S46 in FIG. 12),
obtains, from among these surfaces, a surface
configured by sides having the same size and
15   coincident in their directions of the normal line
vectors and by two straight lines as shown in FIG.
15B, a surface configured by one pair of face-to-face
sides having intersections between the normal line
vectors and by one pair of face-to-face sides having
20   intersections between the normal line vectors and
having the same radius as shown in FIG. 15C and a
surface having intersections between the normal line
vectors of four sides as shown in FIG. 15D (S51),
then calculates areal sizes of these surfaces (S52),
25   and classifies these surfaces according to sizes of
the radiuses. The surface shown in FIG. 15C is,
however, classified based on the radius having the

same size (S53).

Then, the three-dimensional configuration

characteristic extraction unit 12 obtains an areal

size according to every size of the thus classified

5   radius, and acquires the size of the radius with the

areal size coming to the maximum, as a largest

concave shape radius dimension (S54).

The cutting working condition auto setting unit

14 thereby acquires, based on this largest concave

10   shape radius dimension, a diameter of the tool used

before finishing on the occasion of determining the

working condition.

2-6. [Calculation of Maximum Depth]

FIG. 16 is an explanatory view in a case where

15   the three-dimensional configuration characteristic

extraction unit 12 acquires a maximum depth as

configuration information from the three-dimensional

data 100 in step S1.

The three-dimensional configuration

20   characteristic extraction unit 12 divides, based on

the three-dimensional CAD data 100, the surfaces of

the three-dimensional model into the facets,

thereafter acquires, as shown in FIG. 16, Z-axis

values of vertexes with respect to the facets

25   configuring a surface perpendicular to the X-Y plane

of the cutting working machine 2 and abutting on

(coincident in the Z-axis value) the fitting surface

to the cutting working machine 2 or a surface

containing a circular arc and a surface excluding the

fitting surface to the cutting working machine A, and

obtains a difference, as a maximum depth, between

5 Zmax, i.e., the maximum Z-axis value and Zmin, i.e.,

the minimum Z-axis value.

The cutting working condition auto setting

unit 14 thereby selects, mapping to this maximum

depth, a tool having such a length as not to

10 interfere with the work material on the occasion of

determining the working condition.

2-7. [Calculation of Cutting Range Boundary

Line]

FIG. 17 is an explanatory view in a case where

15 the three-dimensional configuration characteristic

extraction unit 12 acquires a cutting range boundary

line as configuration information from the three-

dimensional data 100 in step S1.

The three-dimensional configuration

20 characteristic extraction unit 12 divides, based on

the three-dimensional CAD data 100, the surfaces of

the three-dimensional model into the facets, then

judges whether a normal line of this facet is

perpendicular to the X-Y plane, i.e., parallel with

25 the working axis, and sorts out them into surfaces

configured by the facets exhibiting the parallelism

and the surfaces containing the facets exhibiting

none of parallelisms.

Then, the surfaces with edges shared in each classification are grouped and thus obtained as a working range, and edges, which are not shared with

5   other surfaces in each of groups, are obtained as working range boundary lines. For example, in FIG. 17, surfaces 41, 42, 43 are grouped, wherein edges that are not shared with other surfaces in this group, i.e., an outer periphery of the group that is drawn

10 by a bold line is obtained as a working range boundary line.

The cutting working condition auto setting unit 14 thereby determines this working range boundary line and a working range on the occasion of

15 determining the working conditions. Moreover, the cutting working condition auto setting unit 14, depending on whether the surfaces becoming this working range are surface perpendicular to the working axis or not, determines whether they are cut

20 by a flat end mill or a ball end mill.

2-8. [Calculation of Blank Dimensions]

FIG. 18 is an explanatory view in a case where the three-dimensional configuration characteristic extraction unit 12 acquires blank dimensions as

25 configuration information from the three-dimensional data 100 in step S1.

The three-dimensional configuration

characteristic extraction unit 12 obtains maximum
external configuration dimensions respectively in the
X-, Y- and Z-directions in the procedure shown in FIG.
4 in the same way as in the items 2-1 (S11 ~ S18).

5   Then, the three-dimensional configuration
characteristic extraction unit 12 searches the
working case database 15 for a past cutting working
case where the external configuration dimensions are
most approximate, then obtains a cutting margin

10   (working margin) from this past working case (S61),
temporarily determines the blank dimensions by adding
the thus obtained cutting width to the maximum
external configuration dimensions (S62), makes a
comparison with maximum possible-of-working

15   dimensions of the cutting working machine 2 (S63),
and, in the case of judging that the working by the
cutting working machine 2 is possible (S64),
determines the temporarily determined blank
dimensions as (final) blank dimensions as shown in

20   FIG. 19) (S65).

3. [Determination of Working Conditions Based
on Past Working Results]

The working case database 15 is accumulated per
working case with: the maximum external configuration

25   dimensions (X, Y, Z), the removal volume, the surface
information (about whether the surface is a flat
surface parallel with the working X-Y plane or is a

non-flat surface), the largest concave shape radius
dimension, the minimum concave shape radius dimension
and the maximum depth dimension which have been
extracted by the three-dimensional configuration

5   characteristic extraction unit 12; the cutting
working conditions such as the cutting working step
procedure, the classification of the cutting working
tool, the set number of revolutions of the main
shaft, the feeding speed, the feeding pitch, the Z-

10   cutting quantity, the trajectory of the working tool;
the actual number of revolutions of the main shaft,
the actual feeding speed, the load on the main shaft
in the process of working, the actual cutting time
when the cutting/working is actually conducted; the

15   information on a variety of physical phenomena; and
the information about whether the cutting/working is
judged by the operator to be preferable or not. Note
that FIG. 20 is a conceptual diagram of this working
case database 15.

20   The case searching unit 13 searches this
cutting working case database 15 for a working case
exhibiting a similar configuration, as shown in FIG.
21, on the basis of pieces of configuration
information such as the maximum external

25   configuration dimensions, the removal volume, the
surface information, the largest concave shape radius
dimension, the minimum concave shape radius dimension

and the maximum depth dimension which have been, as described above, acquired by the three-dimensional configuration characteristic extraction unit 12.

5   For example, in case a search condition is the maximum external configuration dimension, a dimensional difference is obtained as an absolute value by comparing a maximum X-axis length of the three-dimensional model with a maximum X-axis length in the working case, similarly dimensional

10   differences in Y- and Z-axis directions are obtained, and, if the values in all the X-, Y- and Z-axis directions are equal to or smaller than values (d) predetermined by the system, it is deemed that the maximum external configuration dimensions take a

15   similar configuration.

Further, in case the search condition is the removal volume, there is obtained a difference in the removal volume (a cutting working volume) between the three-dimensional model and the past working case,

20   and, in a case where an absolute value thereof is equal to or smaller than a value (dV) predetermined by the system, it is deemed that the removal volume is similar.

In case the search condition is the surface

25   information, there is obtained a difference in the areal size of the flat surface parallel with the X-Y plane between the three-dimensional model and the

working case, and, in a case where an absolute value thereof is equal to or smaller than a value (dA) predetermined by the system, it is deemed that the surface information is similar.

5   In case the search condition is the largest concave shape radius dimension, there is obtained a difference in the largest concave shape radius dimension between the three-dimensional model and the past working case, and, in a case where an absolute

10   value thereof is equal to or smaller than a value (dR) predetermined by the system, it is deemed that the largest concave shape radius dimension is similar.

In case the search condition is the minimum concave shape radius dimension, there is obtained a

15   difference in the minimum concave shape radius dimension between the three-dimensional model and the past working case, and, in a case where an absolute value thereof is equal to or smaller than a value (dMR) predetermined by the system, it is deemed that

20   the minimum concave shape radius dimension is similar.

In case the search condition is the maximum depth, there is obtained a difference in the maximum depth dimension between the three-dimensional model and the past working case, and, in a case where an

25   absolute value thereof is equal to or smaller than a value (dD) predetermined by the system, it is deemed that the maximum depth dimension is similar.

The case searching unit 13 searches out the
working case that meets these search conditions, and,
in case the information about whether the working in
this working case is preferable or not is acceptable,
5   the cutting working condition auto setting unit 14
determines the cutting working conditions on the
basis of the number of working steps, the working
tool for use, the feeding speed, the number of
revolutions of the main shaft that are stored by way
10 of this working case.

Note that the cutting working condition auto
setting unit 14 may also optimize the cutting working
conditions as will be mentioned later on in order to
reduce a cutting working time and to improve a
15 working accuracy.

4-1. [Cutting Pitch and Z-Cutting Adjustments
Based on Working Surface Roughness]

In case the cutting working case database 15
has a small number of working cases, and in case
20 there are not any work materials and cutting working
tools nor combinations thereof that show none of the
working cases as a result of the search and a premise
is that the ball end mill is employed as the cutting
working tool, the cutting working condition auto
25 setting unit 14 determines the cutting working
conditions on the basis of standard values stored on
the cutting condition database 16c and values

indicated by the operator from on the pre-working input unit 11.

At this time, theoretical surface roughness is, as shown in FIG. 22, expressed by $H = R - (R^2 - P^2/4)^{1/2}$, where H is a scrap height, P is a feeding pitch and R is a radius of the working tool (which is herein the ball end mill), and hence the scrap height, viz., the theoretical surface roughness is obtained by giving the finishing working tool and the feeding pitch of the cutting working conditions.

Accordingly, the working surface roughness obtained in the cutting working conditions becomes this theoretical surface roughness. Performing the working in fact, however, the actual roughness of the working surface (the actual working surface roughness) might differ depending on a type of the work material, the feeding speed, etc..

Therefore, the cutting working condition auto setting unit 14 effects, as shown in FIG. 23, a recalculation based on the working condition threshold value database 16a so that the working surface roughness required is to be acquired.

Note that the working condition threshold value database 16a is stored with a corresponding relation between the actual working surface roughness and the working conditions in the case of coming to this roughness, the relation being obtained from a cutting

test, the cutting case and the working data, etc. provided from a maker.

To start with, the cutting working condition auto setting unit 14 obtains the theoretical roughness (S71), adds a predetermined allowable value to this theoretical surface roughness, and searches the working condition threshold value database 16a for the actual working surface roughness existing in an allowable value range (S72).

Then, the cutting working condition auto setting unit 14, if the theoretical roughness is not coincident with the actual working surface roughness, searches again with a next candidate tool (S73), and, whereas if coincident, acquires pieces of data of the cutting tool, the work material, the main shaft number-of-revolutions, the feeding speed, the feeding pitch and the actual working surface roughness in this working case. Further, a peripheral speed of the cutting working tool and a feed quantity per edge are obtained by calculation from these pieces of data. Next, the main shaft number-of-revolutions and the feeding speed are obtained by calculations from these calculated values and a diameter of the working tool used for a new working configuration, and results thereof are set as cutting conditions of a new cutting configuration (S74).

The cutting working conditions in which the

working surface roughness required is acquired also in the new configuration having none of the working cases, can be thereby automatically outputted.

4-2. [Control Taking Load on Main Shaft into Consideration]

FIG. 24 shows a procedure of control of properly working by monitoring the main shaft load wen working in steps S7 ~ S9.

The auto NC data creating unit 19 makes the working machine 2 start the working by transmitting NC data creases based on the cutting working conditions given from the cutting working condition auto setting unit 14 to the working machine 2, and simultaneously measures, in the monitoring unit 10, working states (a variety of physical states) of the working machine 2 in real time. At this time, if the main shaft load increases abnormally, this induces a damage to the working machine 2 and deterioration of the cutting workpiece, and therefore the auto NC data creating unit 19 controls so that this main shaft load becomes proper.

To begin with, the auto NC data creating unit 19 obtains an upper value of main shaft load and a proper value of main shaft load from the working machine control unit 22 or the judgment criterion database.

Further, the auto NC data creating unit 19

makes the working machine 2 start the working by transmitting the NC data to the working machine 2 (S82), and obtains the main shaft load from the monitoring unit 10.

5   At this time, the monitoring unit 10 detects a drive current value (a main shaft power P) of an electric motor for driving the main shaft with the sensor unit 22a, and calculates the actual feeding speed from this current value by use of the following

10   formula 1 (S83).

    $t*f = (6120*P*n)/(k*v)$ $\cdots$ (Formula 1)

where t: a pitch (or a cutting depth, mm), f: a feeding speed (mm/min), P: a main shaft power (kW), n: a machine tool efficiency ($\doteqdot 0.8$), k: a specific

15   cutting resistance (that differs depending on the work material), and v: a cutting speed (a tool peripheral speed, m/min).

    The auto NC data creating unit 19 judges whether the working is finished or not (S84), then

20   judges whether or not a main shaft load STR is equal to a proper value ST if not finished (S85), returns to step S82 ad continues the working if equal, obtains, if not equal, such a main shaft power (main shaft electric motor output) P as to become equal

25   thereto (S86), acquires from the formula 1 such a feeding speed as to become this main shaft power P (S87), and transmits such NC data as to become this

feeding speed to the working machine 2 (S82).

Then, in the case of judging that the working is finished (S84), the working case registration unit 17 changes the feed value in the working conditions to a feed value when STR = ST, and registers it in the cutting working case database 15 (S88).

This, even in a case where the set working conditions are not proper, makes it possible to prevent a damage to the working machine 2 and deterioration of the object workpiece by controlling the feeding speed in real time.

Further, a consequence of this working are registered as the working result, and hence the working can be carried out with proper values from the beginning when performing the working next time.

Moreover, this value controlled by monitoring may also be, without being limited to the feeding speed, the main shaft number-of-revolutions, the Z-cutting quantity, the feeding pitched, etc.. Further, these are not singly controlled, but the control items can be also controlled throughout the whole items such as controlling the main shaft number-of-revolutions next to the control of the feeding speed, then controlling the Z-cutting quantity, subsequently controlling the feeding pitch, and so on.

5-1. [Determination of Tool diameter Based on Cutting Range]

FIGS. 25 ~ 27 are explanatory diagrams in the case of obtaining the tool diameter based on the cutting range boundary line acquired in the item 2-7.

The cutting working condition auto setting unit 14, upon acquiring the cutting range boundary line as described above (S101), refers to the tool library 16b, selects the working tool registered in the library 16b in an ascending or descending sequence of the diameter (S102), and disposes it so as to abut at an arbitrary point 51 on the cutting range boundary line as shown in FIG. 25 (S103). Then, the cutting working condition auto setting unit 14 moves the working tool so as to abut at the point 51 on this boundary line at all times (S104), checks whether or not there exists other contact point excluding the point 51 between the tool and the boundary line (S105), and, if it exists, judges whether an angle made by a straight line K1 connecting this point to the center of the working tool and by a normal line K2 across the point on the boundary is 180° or not (S106).

Then, the cutting working condition auto setting unit 14 deems it to be an interference that this angle is an angle other than 180°, selects, moving back to step S102, a next tool from the tool library, then repeats the processing, judges to be usable without any interference whereas if this angle

is 180° (S107), and repeats this process till a largest working tool diameter with no interference is acquired (S108).

5-2. [Determination of Tool Protrusion Quantity Based on Cutting Depth]

FIG. 28 is an explanatory diagram in the case of obtaining a tool protrusion quantity based on the cutting depth acquired in the item 2-6.

The cutting working condition auto setting unit 14, upon obtaining the cutting range boundary line as described above (S91), acquires a protrusion quantity L required at the minimum from the maximum depth (S92), selects from the tool library a cutting working tool having a protrusion quantity that exceeds this minimum protrusion quantity but is a small protrusion quantity or total length by referring to the tool library 16b (S93), then checks, in the case of combining with a designated holder shape designated from a diameter, etc. of the cutting working tool as shown in FIG. 29 (S94), whether or not the three-dimensional model interferes with this holder-attached cutting working tool (S95), deems it usable if not interfered (S96), and deems it unusable if interfered.

In the case of being unusable, a tool approximate to the maximum depth and having a small protrusion quantity or total length is next retrieved

from the tool library, and similarly the interference check is conducted by combining the designated holder.

The cutting working condition auto setting unit 14 selects a working tool suited to the working depth by repeating this the working tool selection, the designated holder fitting and the interference check.

5-3. [Determination of Type of Tool Based on Surface Information]

FIG. 30 is an explanatory diagram in the case of obtaining a type of the working tool on the basis of the surface information acquired in the item 2-3.

The cutting working condition auto setting unit 14 obtains the surface information as described above and classifies them into flat surfaces parallel with the X-Y plane and surfaces unparallel therewith. Then, the cutting working condition auto setting unit 14 selects from the tool library 16C a flat end mill or a bull nose as a tool for working the flat surface parallel with the X-Y plane, and selects from the tool library 16c a ball end mill as a tool for working the flat surface unparallel with the X-Y plane of the working coordinates and a non-flat surface.

6. [Detection of Tool Life-Time or Breakage]

FIG. 31, FIG. 32 are explanatory charts for detecting a tool line-time or breakage.

The NC data automatically created by the auto

NC data creating unit 19 are sent to the working

machine control unit 22, and, when the cutting

working machine 2 starts working, the monitoring unit

10 measures in real time a variety of physical states

5   in the process of working on the basis of the values

detected by the sensor unit 22a.

    The auto NC data creating unit 19 avoids a

breakage by controlling the cutting working

conditions in real time in accordance with generated

10   ultrasonic waves when a working tool material comes

to a breakage among physical phenomena monitored by

this monitoring unit 10, or controls the cutting

working conditions of the next time in a way that

changes the cutting condition database 16c after the

15   cutting/working.

    In the case of controlling the cutting working

conditions in real time, the auto NC data creating

unit 19, as shown in FIG. 31, at first starts

monitoring (step A1, which will hereinafter be

20   abbreviated such as A1), judges whether or not a

quantity of ultrasonic waves intrinsic to the working

tool material per unit time is equal to or larger

than a predetermined value and whether or not a total

number of generated ultrasonic waves is equal to or

25   larger than a predetermined value (A3), and, in the

case of exceeding this predetermined value, namely, a

value from which to enable a prediction of an

abnormal abrasion/breakage phenomenon of the working tool that is predetermined from the working test and the cutting/working experience (YES in A2)m or in case the number of generated ultrasonic waves during the cutting/working exceeds a value just before an expiration of the life-time and the breakage of the working tool (YES in A3), transmits an instruction (NC data) with the cutting working conditions changed to the cutting working machine 3 or via the cutting machine control unit 22 to the cutting working machine 2.

Herein, in case the change in the cutting working conditions is a change in the feeding speed (YES in A4), an instruction of decreasing the feeding speed by a fixed value at a predetermined rate is outputted to the cutting working machine 2 or via the working machine control unit 22 to the cutting working machine 2, and this is repeated till the number of generated ultrasonic waves becomes equal to or smaller than the predetermined value (A5). For example, in a case where the feeding speed has been set at F1000, that is done till it comes to F900. Even by doing so, in case the number of generated ultrasonic waves of the tool cannot be restrained, the feeding speed is decreased stepwise such as F800, F700… during the cutting/working.

Moreover, in case the change in the cutting

conditions is a change in the main shaft number-of-revolutions (NO in A4), an instruction of decreasing the main shaft number-of-revolutions by a fixed value at a predetermined rate is outputted to the cutting

5   working machine 2 or via the working machine control unit 22 to the cutting working machine 2 (A6), further a quantity of the ultrasonic waves per unit time is measured, determining the main shaft number-of-revolutions is repeated, and this is conducted

10   till the number of generated ultrasonic waves becomes equal to or smaller than the predetermined value.

Furthermore, in the case of changing the cutting condition database 16c after the cutting/working, as shown in FIG. 32, the

15   cutting/working is performed according to the first NC data without changing the cutting conditions during the cutting/working, and the number of generated ultrasonic waves related to the abnormal abrasion/breakage phenomenon that has been monitored

20   is temporarily stored on the storage device 33.

Then, after the cutting/working has been finished, the monitoring unit 10 judges whether or not the number of generated ultrasonic waves per unit time which has been temporarily recorded on the

25   storage device 33 is equal to or larger than the predetermined value (A10) or whether or not a total number of generated ultrasonic waves is equal to or

larger than a predetermined value (A11). In the case
of judging in steps A10, A11 that the number of
generated ultrasonic waves is equal to or larger than
the predetermined value, the monitoring unit 10

5   judges whether the setting of the cutting condition
is the change in the feeding speed or not (A12) and
transmits, in the case of the change in the feeding
speed, this piece of information to the working case
registration unit 17, and the working case

10   registration unit 17 decreases the feeding speed in
the cutting condition database 16c by a predetermined
value (A13).

        Moreover, if the setting of the change in the
cutting conditions is not the change in the feeding

15   speed, it is judged whether or not this is a change
in the main shaft number-of-revolutions (A14) or
whether this is a changed in the feeding pitch or not
(A15), in the case of YES, this piece of information
is transmitted to the working case registration unit

20   17 in the same way as in the case of the feeding
speed, and the working case registration unit 17
decreases the main shaft number-of-revolutions in the
cutting condition database 16c by a predetermined
value (A15) or decreases the feeding pitch by a

25   predetermined value (A17).

        Moreover, in case the setting of the change in
the cutting conditions is none of the changes given

above, the working case registration unit 17
decreases the Z-cutting quantity in the cutting
condition database 16c by a predetermined value (A18).

As a result, in the setting of the cutting
5   working conditions from the next time onwards, it
follows that the working conditions, which this
change is reflected in, and the NC data can be
outputted.

The above operations are effected, whereby the
10   cutting working conditions can be automatically
controlled so as not to cause the occurrence of the
abnormal abrasion of the tool when employing the same
type of working tool.

In the embodiment, the physical phenomenon has
15   been explained as the ultrasonic waves, however, the
physical phenomena may be not only the ultrasonic
waves but also, if being phenomena detectable by the
sensor, sounds or vibrations perceptible to the five
senses of a human being, a change in configuration
20   and a suing time of the tool and further physical
phenomena unperceptible to the five senses of the
human being such as the ultrasonic waves.

7. [Control Dealing with Plural Tools as Set of
Working Tools]

25   It is general that the cutting/working is
conducted by separating it into a plurality of
processes such as rough working, intermediate

finishing working and finishing working. In this case, to begin with, the cutting is roughly done by a tool for rough working, and next this cutting residual is cut by a tool for the intermediate

5 finishing working. At this time, as shown in FIG. 33A, if a tool C exhibiting an excessive cutting quantity is selected as the tool for the intermediate finishing working, it follows that more of cutting than needed is to be done, resulting in rough

10 finishing. Therefore, it is required that a tool B capable of cutting the cutting residual and cutting to such an extent that the finishing working can be done by the tool A for finishing working as shown in FIG. 33B, be selected. Thus, in the case of

15 selecting the tool, it is desirable that the selection be made taking into account the tools used before and after it.

　　Such being the case, in the embodiment, as shown in FIGS. 34, 35, the selection is made in a way

20 that deals with the plurality of tools as a set (FIG. 33C).

　　To start with, the three-dimensional configuration characteristic extraction unit 12 of the system extracts the configuration information of

25 the three-dimensional model for performing a working process design (B1). Next, the case searching unit 13 searches the working case database 15 for pieces

of configuration information, i.e., the maximum
external configuration dimensions, the removable
volume, the surface information, the largest concave
shape radius dimension, the minimum concave shape

5   radius dimension, the maximum depth and the cutting
range boundary line, and searches out a working case
in which these pieces of configuration information
are coincident within a predetermined allowable range
and the working result is preferable (B2).

10   The cutting working condition auto setting unit
14 extracts a diameter of a single or a plurality of
working tools used in this working case, a working
tool holder, a tool material and a type such as a
tool edge shape, etc. batchwise as a working tool set,

15   and uses them as initial values in the new working
process design (B3).

        Next, the cutting working condition auto
setting unit 14 assigns the working process to each
of the tools extracted. For example, in case this

20   searched-out working tool set is ball end mills
having a diameter of 10 mm, a diameter of 6 mm, a
diameter of 3 mm and a diameter of 1 mm, a first
working process is assigned to the diameter of 10 mm,
a second working process is assigned to the diameter

25   of 6 mm, a third working process is assigned to the
diameter of 3 mm, and a fourth working process is
assigned to the diameter of 1 mm, thus assigning the

working processes to the working tools from the largest diameter of the working tool down to the smallest diameter thereof (B4).

5   Next, the cutting working condition auto setting unit 14 obtains a cutting residual quantity per working process assigned, and, if there is a gap between the cutting residual quantity and the allowable range of the next tool, adds tools. A cutting residual volume of an n-th tool is obtained

10   by, for instance, a method or the like of calculating the cutting residual part as shown in FIG. 22, and, if this is a larger than the allowable range (the Z-cutting quantity + a coefficient) of the next tool, an interpolation working process is automatically

15   added to between an n-th working process and an (n+1)th working process subsequent thereto (B5).

    Next, the cutting working condition auto setting unit 14, if the cutting residual quantity is small and falls within the allowable range of the

20   next tool even when there are none of the tools, deletes this tool for efficiency. For example, if the cutting residual quantity of the n-th tool falls within the allowable range of an (n+2)th tool, the (n+1)th tool is deleted (B6).

25   Then, the cutting working condition auto setting unit 14 determines the tool set undergoing the execution of this adding/deleting process, as the

using tools (B7).

This makes it feasible to design the working process that automatically uses the proper tools.

8. [Control of Determining Tool and Working Process from Target Time]

FIGS. 3, 36, 37, 38 are explanatory diagrams of control of determining the tool and the working process from a target time. As shown in the same Figures, the working control device of the invention executes respective steps of a method of determining the tool and the working process in accordance with the working control program (including a tool determining program).

To begin with, in step 1, the three-dimensional configuration characteristic extraction unit 12 acquires a final configuration (a configuration of an object workpiece) and a blank configuration from three-dimensional CAD data of the object workpiece, and acquires an area, as a removal area, into which the final configuration is removed from the blank configuration. For instance, in FIG. 36A, a solid black area represents the final configuration, a rectangular area drawn by a bold line represents the blank configuration, and a white-base area inside the blank configuration represents the removal area. Note that the blank configuration is acquired from the three-dimensional CAD data in the same way as in

the item 2-8 in the embodiment. In the embodiment, the three-dimensional configuration characteristic extraction unit 12 obtains the removal area by removing the final configuration from the blank

5   configuration (namely, a volume of the removal area is obtained by subtracting a volume of the final configuration from a volume of the blank), however, without being limited to this, only the final configuration is obtained in step 1, the blank

10   configuration is inputted in step 2, and the cutting working condition auto setting unit 14 may acquire the removal area by removing the final configuration from the blank configuration in step 5.

In step 2, the pre-working input unit 11

15   accepts an input of pieces of object workpiece information such as a classification of a product, a material of the workpiece, etc.. Note that the cutting working case database is previously stored with a cutting quantity (a reference cutting

20   quantity) per unit time which serves as a reference, mapping to the object workpiece information such as the classification of the product, the material of the workpiece, etc..

In step 3, the case searching unit 13 searches

25   the cutting working case database and thus obtains the cutting quantity mapping to the classification of the product and the material of the workpiece, as a

working case.

In case this working case is searched out (S4), moving to step 5, the cutting working condition auto setting unit 14 determines, based on this working case, the working conditions, i.e., the tool and the working process.

FIG. 37 is the chart showing in detail a procedure of determining the tool and the working process in step 5.

As shown in the same chart, the cutting working condition auto setting unit 14 executes steps 501 ~ 508 that follow.

In step 501, a minimum tool diameter required for the cutting/working is determined based on the information about the usable tool information stored on the tool library and the three-dimensional CAD data. Namely, the minimum concave shape radius dimension is obtained as in the item 2-4 from the three-dimensional CAD data, and, among the diameters of the tools stored on the tool library, a diameter that is equal to or smaller than but most approximate to this dimension is set as the minimum tool diameter.

The tool library is stored with the tool diameter of the usable tool, the feeding speed, the pitch, the Z-cutting quantity and the cutting quantity per unit time as shown in, e.g., Table 1.

[Table 1]

n	TOOL DIAMETER (mm)	FEEDING SPEED (mm/min)	PITCH (mm)	z-CUTTING QUANTITY (mm)	CUTTING QUANTITY PER UNIT TIME (mm^3/min)
1	$\phi 1$	450	0.25	0.1	11.25
2	$\phi 2$	480	0.5	0.2	48
3	$\phi 3$	560	0.75	0.3	126
4	$\phi 4$	640	1	0.4	256
5	$\phi 6$	700	1.5	0.6	630
6	$\phi 8$	800	2	0.8	1280
7	$\phi 10$	820	2.5	1	2050
8	$\phi 12$	740	3	1.2	2664

In step 502, a target time T of the cutting/working is determined based on the working case searched out by the case searching unit 13. Namely, the target time T is calculated by dividing the volume of the removal area by the reference cutting quantity.

In step 503, a time T1 when the entire removal area is cut by a tool TL1 having the minimum tool diameter, is calculated. That is, the cutting time T1 is obtained by dividing the volume of the removal area by the cutting quantity, per unit time, of the tool TL1.

In step 504, the target time T is compared with the cutting time T1, and there moves to step 505 if T

$< T1$ and to step 507 if $T = T1$.

In step 505, the tools are added in sequence from the tool having the minimum tool diameter, and a cutting time Tn in the case of effecting the

5 cutting/working with the tools inclusive of the n-th tool, is calculated. The tools to be added, which have diameters larger than the diameter of the tool with the cutting time already calculated, are extracted by every predetermined number of pieces

10 from among the usable tools. For instance, if the minimum tool diameter is $F1$ and if extracted one by one, a tool having a tool diameter of $F2$ is added as $T12$. Further, the predetermined number of pieces are stored mapping to the object workpiece information on

15 the cutting working case database and may also be a value searched out mapping to the object workpiece information. For instance, if the classification of the product is a die mold, the extraction is done one by one, and, if being a box body for a personal

20 computer, the extraction is done by every twos.

Moreover, in step 505, the cutting time Tn is calculated, wherein the cutting/working for the Z-cutting quantity is performed with the tools inclusive of $TLn-1$ when the n-th tool is set as TLn,

25 and a time for which the residual cutting/working is effected with the tool TLn is set as the time Tn. Namely, in step 503, as indicated by a hatching area

in FIG. 36B, the working time when the entire removal area is cut by the tool TL1 is obtained, while in step 505, in the case of adding the second tool TL2, the cutting is conducted with the tool TL1 by the Z-cutting quantity as shown in FIG. 36C (the hatching area), and a time T2 when a residual vertical line area is cut with TL2, is obtained. Moreover, in the case of adding TL3, as shown in FIG. 37C, a time T3 is obtained.

For example, in the case of working a blank (workpiece) of 100 X 80 X 50 (mm) in a final configuration as shown in FIG. 38A, the minimum tool diameter is set to $\Phi 1$, the tools registered on the tool library shown in Table 1 are added one by one, in the case of working with seven pieces of tools, as shown in FIG. 38B, the cutting/working is effected respectively with the tools of TL1 through TL6 by the Z-cutting quantity, and the residual cutting/working is done with the a tool TL7.

Table 2 shows volumes cut respectively by the tools TL1 ~ TL8 in the case of performing the working by n-pieces of tools.

[Table 2]

n	TOOL DIAMETER	φ1	φ2	φ3	φ4	φ6	φ8	φ10	φ12
1	φ1	144000							
2	~φ2	1360.8	142639.2						
3	~φ3	1360.8	2726.4	139912.8					
4	~φ4	1360.8	2726.4	4101.6	135811.2				
5	~φ6	1360.8	2726.4	4101.6	5491.2	130320			
6	~φ8	1360.8	2726.4	4101.6	5491.2	8284.8	122035.2		
7	~φ10	1360.8	2726.4	4101.6	5491.2	8284.8	11136	110899.2	
8	~φ12	1360.8	2726.4	4101.6	5491.2	8284.8	11136	14064	96835.2

Namely, the cutting time T_n in the case of effecting the cutting/working by each number of pieces is a sum of the time when cut with the tools $TL_1 \sim TL_{n-1}$ by the Z-cutting quantity and the time when the residual cutting is done with the tool TL_n.

Table 3 shows the cutting time Tn in the case of effecting the cutting/working with each number of pieces.

5　　　　　[Table 3]

n	TOOL DIAMETER (min)	CUTTING TIME Tn(min)
1	$\phi 1$	12800
2	$\sim \phi 2$	3093
3	$\sim \phi 3$	1288
4	$\sim \phi 4$	741
5	$\sim \phi 6$	439
6	$\sim \phi 8$	340
7	$\sim \phi 10$	308
8	$\sim \phi 12$	297

In step 506, the cutting time Tn is compared with the target time T, the tool is added if T < Tn, the process (S505) of calculating the cutting time Tn 10　is repeated, and there moves to step 507 if T = Tn.

In step 507, the using tool is determined from among the n-pieces of tools at a point of time when the cutting time Tn becomes shorter than the target time. Namely, if the cutting time T1 is equal to or 15　less than the target time T, only the tool TL1 is used, and, if equal to or less than the target time T when the cutting time Tn = T5, the using tool is determined from among TL1 ~ TL5. For example, if the

target time is 330 sec in an example of the Table 3,
the using tool is determined from among TL1 ~ TL7.

Note that the method of determining the using
tool from the plurality of tools is arbitrary, all
the tools may be used, and a predetermined number of
pieces may also be selected. For instance, in the
case of selecting three pieces from among n-pieces of
tools (n is three or larger in this case), a tool
having the minimum diameter, a tool having the
maximum diameter and one piece of tool having an
intermediate diameter therebetween are selected.
Similarly, in the case of selecting four pieces from
among the n-pieces of tools, the tool having the
minimum diameter, the tool having the maximum
diameter and two pieces of tools having the
intermediate diameter therebetween are selected.

In step 508, the working process is determined
in sequence from the largest tool diameter among the
selected tools. For example, in case this searched-
out working tool set is ball end mills having a
diameter of 10 mm, a diameter of 6 mm, a diameter of
3 mm and a diameter of 1 mm, a first working process
is assigned to the diameter of 10 mm, a second
working process is assigned to the diameter of 6 mm,
a third working process is assigned to the diameter
of 3 mm, and a fourth working process is assigned to
the diameter of 1 mm, thus assigning the working

processes to the working tools from the largest diameter of the working tool down to the smallest diameter thereof.

Then, processes from step 7 onwards are executed by use of the determined tools and the working processes.

Thus, the tools are added in sequence from the tool TL1 having the minimum tool diameter, the tool Ln when the target time is reached is obtained, and the tools are determined to use TL1 ~ TLn, whereby the target time is set from general pieces of information such as the classification of the product, the material of the blank and the tools can be easily determined even in a case where the cutting working case database has none of the similar working cases.

Further, in the case of determining the tools in sequence from the largest diameter as a man determines the tools, irrespective of the configuration of the object workpiece, a calculation as to whether the tool is usable or not in sequence from the largest tool among those registered on the tool library, must be performed, however, the tool having the minimum tool diameter can be uniquely obtained from the three-dimensional CAD data of the object workpiece, and, if the tools are determined in a diameter decreasing sequence from the tool having the smallest diameter, the tools and more essentially

the working processes can be determined.

9. [Control of Determining Tool and Working Process from Reduction Time]

FIGS. 3 and 39 are explanatory diagrams of

5   control of determining the tool and the working process from a reduction time. As shown in the same Figures, the working control device of the invention executes respective steps of a method of determining the tool and the working process from the reduction

10   time in accordance with the working control program (including the tool determining program).

At first, in step 1, the three-dimensional configuration characteristic extraction unit 12 acquires a final configuration (a configuration of an

15   object workpiece) and a blank configuration from the three-dimensional CAD data of the object workpiece, and acquires an area, as a removal area, into which the final configuration is removed from the blank configuration (namely, a volume of the removal area

20   is obtained by subtracting a volume of the final configuration from a volume of the blank). In the embodiment, the three-dimensional configuration characteristic extraction unit 12 obtains the removal area, however, without being limited to this, only

25   the final configuration is obtained in step 1, the blank configuration is inputted in step 2, and the cutting working condition auto setting unit 14 may

acquire the removal area by removing the final configuration from the blank configuration in step 5.

In step 2, the pre-working input unit 11 accepts an input of pieces of object workpiece information such as a classification of a product, a material of the workpiece, etc.. Note that the cutting working case database is previously stored with a cutting quantity (a reference cutting quantity) per unit time which serves as a reference for determining the tool, mapping to the object workpiece information such as the classification of the product, the material of the workpiece, etc..

In step 3, the case searching unit 13 searches the cutting working case database and thus obtains a reference value mapping to the classification of the product and the material of the workpiece, as a working case.

In case this working case is searched out (S4), moving to step 5, the cutting working condition auto setting unit 14 determines, based on this working case, the working conditions, i.e., the tool and the working process.

FIG. 39 is the chart showing in detail a procedure of determining the tool and the working process in step 5.

As shown in the same chart, the cutting working condition auto setting unit 14 executes the following

steps.

In step 511, a minimum tool diameter required for the cutting/working is determined based on the information about the usable tool information stored on the tool library and the three-dimensional CAD data. Namely, the minimum concave shape radius dimension is obtained as in the item 2-4 from the three-dimensional CAD data, and, among the diameters of the tools stored on the tool library, a diameter that is equal to or smaller than but most approximate to this dimension is set as the minimum tool diameter.

The tool library is stored with the tool diameter of the usable tool, the feeding speed, the pitch, the Z-cutting quantity and the cutting quantity per unit time as shown in, e.g., Table 1.

In step 512, a reduction time of the cutting/working is determined based on the working case (the reference value) searched out by the case searching unit 13. Namely, the reduction time (e.g., 30 min.) is calculated by dividing the value of the removal area by the reference value. This reduction time may be a time difference a between the cutting time Tn and the cutting time Tn-1 and may also be a rate ß (a reduction rate: Tn/Tn-1) of the cutting time Tn-1 to the cutting time Tn. Further, in the example, the time difference is determined by calculating the reference value searched out, however,

without being limited to this, the reduction time (the time difference a and the reduction rate ß) is stored beforehand mapping to the object workpiece information, and the working case searched out by the case searching unit 13 may be determined directly as the reduction time.

In step 513, a time T1 when the entire removal area is cut by a tool TL1 having the minimum tool diameter, is calculated. That is, the cutting time T1 is obtained by dividing the volume of the removal area by the cutting quantity, per unit time, of the tool TL1.

In step 514, the tools are added in sequence from the tool having the minimum tool diameter, and the cutting time Tn in the case of effecting the cutting/working with the tools inclusive of the n-th tool, is calculated. The tools to be added, which have diameters larger than the diameter of the tool with the cutting time already calculated, are extracted by every predetermined number of pieces from among the usable tools.

In this step 514, the cutting time Tn is calculated, wherein the cutting/working for the Z-cutting quantity is performed with the tools inclusive of TLn-1 when the n-th tool is set as TLn, and a time for which the residual cutting/working is effected with the tool TLn is set as the time Tn.

Table 2 shows volumes cut respectively by the tools TL1 ~ TL8 in the case of performing the working by n-pieces of tools.

Namely, the cutting time Tn in the case of effecting the cutting/working by each number of pieces is a sum of the time when cut with the tools TL1 ~ TLn-1 by the Z-cutting quantity and the time when the residual cutting is done with the tool TLn.

In step 515, the cutting time Tn with the tool TLn is compared with the cutting time Tn-1 with the tools TL1 ~ TLn-1, in a case where the time Tn becomes shorter by the reduction time (corresponding to a predetermined value) or above than the time Tn-1, namely, if Tn-1 = a + Tn (or Tn = ß X Tn-1), the process (S514) of calculating the cutting time Tn by adding the tool is repeated, and, in case the cutting time Tn does not become shorter by the reduction time or above than the cutting time Tn-1, namely, if Tn-1 < a + Tn (or Tn > ß X Tn-1), there moves to step 516.

Table 4 shows the reduction time (the time difference a and the reduction rate ß) in the case of performing the cutting/working with each number of tools.

[Table 4]

n本	TOOL DIAMETER (min)	CUTTING TIME Tn(min)	TIME DIFFERENCE (min)	REDUCTION RATE (%)
1	$\phi 1$	12800		
2	$\sim \phi 2$	3093	9707	75.8
3	$\sim \phi 3$	1288	1804	58.3
4	$\sim \phi 4$	741	547	42.5
5	$\sim \phi 6$	439	302	40.8
6	$\sim \phi 8$	340	98	22.4
7	$\sim \phi 10$	308	33	9.6
8	$\sim \phi 12$	297	11	3.5

In step 516, the using tool is determined from among (n-1)-pieces of tools at a point of time when the time Tn does not shorter by the predetermined value or above than the time Tn-1. That is, if the cutting time T1 is less than a + T2, only the tool TL1 is employed, and, if the cutting time Tn-1 = T5 comes to less than a + T6, the tool is determined from among TL1 ~ TL5. For example, in the example in Table 4, if the time difference a is 30 min. or if the reduction rate ß is 10%, the tool is determined from among TL1 ~ TL7.

Note that the method of determining the using tool from the plurality of tools is arbitrary, all the tools may be used, and a predetermined number of pieces may also be selected. For instance, in the case of selecting three pieces from among n-pieces of

tools (n is three or larger in this case), a tool having the minimum diameter, a tool having the maximum diameter and one piece of tool having an intermediate diameter therebetween are selected.

5   Similarly, in the case of selecting four pieces from among the n-pieces of tools, the tool having the minimum diameter, the tool having the maximum diameter and two pieces of tools having the intermediate diameter therebetween are selected.

10   In step 517, the working process is determined in sequence from the largest tool diameter among the selected tools. For example, in case this searched-out working tool set is ball end mills having a diameter of 10 mm, a diameter of 6 mm, a diameter of

15   3 mm and a diameter of 1 mm, a first working process is assigned to the diameter of 10 mm, a second working process is assigned to the diameter of 6 mm, a third working process is assigned to the diameter of 3 mm, and a fourth working process is assigned to

20   the diameter of 1 mm, thus assigning the working processes to the working tools from the largest diameter of the working tool down to the smallest diameter thereof.

        Then, the processes from step 7 onwards are

25   executed by use of the determined tools and the working processes.

        Thus, the tools are added in sequence from the

tool TL1 having the minimum tool diameter, the tool

Ln when the target time is reached is obtained, and

the tools are determined to use TL1 ~ TLn, whereby

the target time is set from general pieces of

5   information such as the classification of the product,

the material of the blank, etc. and the tool can be

easily determined even in a case where the cutting

working case database has none of the similar working

cases.

10   Further, in the case of determining the tools

in sequence from the largest diameter as a man

determines the tools, irrespective of the

configuration of the object workpiece, a calculation

as to whether the tool is usable or not in sequence

15   from the largest tool among those registered on the

tool library, must be performed, however, the tool

having the minimum tool diameter can be uniquely

obtained from the three-dimensional CAD data of the

object workpiece, and, if the tools are determined in

20   a diameter decreasing sequence from the tool having

the smallest diameter, the tools and more essentially

the working processes can be determined.

§3. Effects of Embodiment

As described above, according to the embodiment,

25   the working configuration characteristics of how the

man has been recognizing the working configuration

and determining the cutting process, the using tool,

the cutting conditions, etc. from the experiences,
are used as the search key to search for the similar
working case, the working conditions are determined
based on this, and the processes of how the man
5   determines the working conditions as the brain
conceives are systematized, thereby enabling the
inexperienced person for the cutting/working to
perform the cutting/working in safety with the high
quality in a way that restrains a scatter in quality,
10   which depends on the know-how and the experiences of
other persons.

      Further, the numerical value data are acquired
form the actual working phenomena and accumulated as
the working cases on the database, and this enables
15   them to be retrieved corresponding to the
characteristics of the working configuration, whereby
the know-how, which could not be so far left except
as a memory of the experienced person, is left as the
database and made thus reusable.

20   Moreover, as for the object workpiece about
which the there is no cutting/working experience, the
proper tool and process can be easily determined
based on the general pieces of information (the
default values) such as the classification of the
25   product, the material of the blank, etc.. Further,
it is possible to restrain the scatter in working
quality depending on the difference in experience

between the operators. Still further, the tool and
the process can be efficiently determined by the
search starting from the minimum tool diameter.